



2025 VISTING FELLOWS PROGRAM

THE IMPACT OF DIGITAL TECHNOLOGY ON DIGITAL TRADE AND WELFARE: EVIDENCE FROM THE CAREC REGION

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June 2026



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Scholars were encouraged to conduct research on CAREC integration topics and comparative analyses between (sub) regions to obtain insights to promote and deepen regional integration among CAREC member countries, as anticipated in the CAREC 2030 strategy and stated operational priorities.

Dr. Ivan Li wrote the paper, Dr. Kaut Akizhanov, Deputy Director of the Central Asia Regional Economic Cooperation Institute, advised on the study. Ms. Emma Tong, and Ms. Si Dan, research specialists of the CAREC Institute, gave grant administration support and coordination throughout the process. The CAREC Institute's Publication Board reviewed the paper and provided comments for improving it. The research is funded through technical assistance from the Asian Development Bank (ADB) under TA-6694 REG: Supporting the Central Asia Regional Economic Cooperation Institute-International Expert (CAREC Institute Visiting Fellow-Batch 3)

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Abstract

We estimate the trade and welfare effects of digital technology adoption, focusing on the Central Asia Regional Economic Cooperation region. By constructing bilateral measures of digital technology that incorporate measures of digital infrastructure, components, and platforms, we identify the specific channels through which technology reduces trade costs. Using a gravity framework applied to digital services exports (2005–2021), we find that physical digital infrastructure is the strongest correlate of digital trade. A one-standard-deviation increase in infrastructure is associated with a 43% increase in bilateral digital trade, on average across country pairs in our sample. This effect substantially exceeds the estimated impact of digital provisions in preferential trade agreements, which exhibit only a negligible effect. Counterfactual simulations further suggest that a policy of regional infrastructure convergence would generate approximately \$915M in additional annual digital services exports (95% CI: \$494M–\$1,397M). Afghanistan and Pakistan are estimated to capture the majority of these gains, although the precise distribution should be interpreted cautiously given data quality limitations in both countries. Overall, the findings suggest that for developing economies, the returns to digital infrastructure investment are considerably larger than those associated with legal harmonization through trade agreements.

Keywords: Digital technology, Digital trade, Gravity model, CAREC region, Trade policy, Welfare

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List of Abbreviations

Abbreviation	Full Term
ASEAN	Association of Southeast Asian Nations
BaTIS	Balanced Trade in Services (OECD–WTO dataset)
CAREC	Central Asia Regional Economic Cooperation
CES	Constant Elasticity of Substitution
CI	Confidence Interval
DESTA	Design of Trade Agreements database
DP	Digital Provisions (in PTAs)
DTI-B	Bilateral Digital Technology Index
FE	Fixed Effects
GVC	Global Value Chain
HIC	High-Income Country
ICT	Information and Communications Technology
IMF	International Monetary Fund
LIC	Low-Income Country
LMIC	Lower-Middle-Income Country
MNC	Multinational Corporation
OECD	Organisation for Economic Cooperation and Development
PPML	Poisson Pseudo-Maximum Likelihood
PTA	Preferential Trade Agreement
SE	Standard Error
TAPED	Trade Agreements Provisions on Electronic-Commerce and Data database
TFP	Total Factor Productivity
TiSMoS	Trade in Services by mode of Supply (WTO)
UNCTAD	United Nations Conference on Trade and Development
WDI	World Development Indicators (World Bank)
WTO	World Trade Organization

Introduction

Global trade has shown sharply divergent growth patterns over the past two decades. Although traditional goods trade has expanded at a relatively modest annual rate of 6%, digital product exports grew by 24.6% annually between 2016 and 2021.² This trend is consistent with a shift in the primary determinants of trade costs from physical barriers to digital constraints, although causal attribution warrants caution. Despite the clear aggregation, the mechanisms driving this shift and its implications for digital integration in developing economies remain insufficiently understood.

We examine the dynamics of digital trade and the welfare effects of digital technology adoption, focusing on the Central Asia Regional Economic Cooperation (CAREC) region whose countries exhibit substantial variation in digital readiness while sharing a common objective of regional integration. Policy discussions in the region have largely emphasized "soft" integration through digital provisions in preferential trade agreements (PTAs). However, if the principal barrier to digital trade is not regulatory divergence but limitations in data transmission capacity, then trade agreements are likely to yield limited marginal returns in the absence of adequate infrastructure investment.

Our analysis addresses a central policy question of the CAREC 2030 agenda, "which measurable factors enable countries to participate in digital trade?" We move beyond the broad digitalization indices commonly used in prior studies by developing bilateral measures of digital technology across three dimensions: physical infrastructure (broadband and servers), intermediate components, and platform ecosystems. These categories capture distinct layers of technology that facilitate trade flows within a standard gravity framework.

We apply a structural gravity model to bilateral trade data covering 190 countries from 2005 to 2021. Our estimates provide two main findings. First, physical digital infrastructure is the dominant correlate of digital trade. A one-standard-deviation improvement in infrastructure is associated with a 43% increase in bilateral digital trade, on average across country pairs. Moving from the 25th to the 75th percentile of infrastructure quality is associated with a 55% increase in trade, although this average effect masks heterogeneity across country pairs and development levels. Second, trade policy appears to play a secondary role. While general PTAs are associated with higher trade volumes, the marginal effect of adding digital provisions is statistically small (5%) and economically negligible relative to infrastructure effects.

The infrastructure gap presents both an opportunity and a constraint. Five CAREC countries already operate at or above the Association of Southeast Asian Nations (ASEAN) median infrastructure level, demonstrating that advanced connectivity is attainable within the region. However, Afghanistan, the Kyrgyz Republic, Pakistan, Tajikistan, and Turkmenistan remain substantially behind, with infrastructure scores ranging from 11% to 72% below the regional median. Building on our gravity estimates, we conduct counterfactual simulations to quantify the potential gains from infrastructure improvements.

Under a regional convergence scenario that raises the five below-median countries to the CAREC median infrastructure level (0.166), annual digital services exports are estimated to increase by approximately \$915 million (95% CI: \$494M–\$1,397M). A more ambitious convergence to the ASEAN benchmark would generate an estimated \$1,186 million annually (95% CI: \$631M–\$1,841M). These projections are anchored to the statistically significant infrastructure elasticity from our preferred specification ($\beta = 3.769$, $p < 0.001$), with confidence intervals reflecting parameter uncertainty. The

² Stojkoski, V., Koch, P., Coll, E. *et al.* Estimating digital product trade through corporate-revenue data. *Nat Commun* 15, 5262 (2024). <https://doi.org/10.1038/s41467-024-49141-z>

results consistently identify physical connectivity as the dominant correlate of digital trade, although the projected magnitudes should be interpreted as indicative ranges rather than precise forecasts.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature and highlights gaps in our understanding of digital trade in developing regions. Section 3 describes the data and gravity-model framework. Section 4 presents the baseline results and robustness checks. Section 5 reports the counterfactual analysis of infrastructure investment scenarios. Section 6 concludes with policy implications.

2. Literature Review

Two strands of the literature underpin this study:

- Empirical research examining how digital technology affects trade margins (both extensive and intensive), and
- More recent work on digital trade measurement and governance. We organize the review around three questions:

What do we know about the effects of infrastructure on digital trade? How and to what extent do digital trade policies affect trade? What gaps remain in our understanding of digital trade growth in developing economies? The objective is to answer these questions in this paper.

2.1. Digital Infrastructure and Connectivity Effects on Trade

The expansion of digital networks has fundamentally altered the structure of trade costs. One direct mechanism is that the internet functions as a global marketplace, reducing firm fixed market-entry costs by lowering information frictions. Freund and Weinhold (2004) showed that growth in web-host availability is associated with trade expansion. Subsequent research demonstrates considerable heterogeneity in this effect. For example, Lin (2015) found relatively modest impacts, with a 10% increase in internet users raising international trade by only 0.2%–0.4%, whereas Herman and Oliver (2023) reported trade-creation effects exceeding 30% when internet adoption rises jointly across trading partners.

Early studies often overlooked heterogeneity across digital technologies. However, the specific layer of technology matters. Azu (2024), for example, found that transport infrastructure drives goods exports, whereas information and communication technology (ICT) infrastructure is the binding constraint for imports. This distinction is particularly relevant for developing economies. Improvements in “hard” infrastructure, such as submarine cable deployment, are more likely to generate immediate causal effects on employment and trade capacity (Hjort and Poulsen, 2019; Cariolle, 2021). The broader consensus is that connectivity reduces the information asymmetries that isolate peripheral markets (Clarke and Wallsten, 2006).

A persistent challenge in this literature is the reliance on broad aggregate proxies for digitalization, such as internet penetration rates. Such measures implicitly assume that all digital technologies affect trade similarly, from basic connectivity to advanced platform ecosystems. This approach overlooks the possibility that physical infrastructure may influence trade differently from digital components or platform openness. We address this limitation by constructing bilateral measures that distinguish between these dimensions. Our results indicate that, when separated, physical infrastructure is the primary driver of cross-border digital trade.

2.2. Digital Trade Policy and Governance Frameworks

Digital trade governance is shaped by a fundamental tension between the free flow of cross-border digital trade and the territorial sovereignty of data. Early theories anticipated the emergence of a borderless marketplace as digital trade expanded. However, the contemporary policy landscape has fragmented into competing regulatory models. The U.S. generally promotes data flows and market access, reflecting the global prominence of its digital firms. The E.U. advances a rights-based framework centered on data privacy (General Data Protection Regulation) and digital sovereignty. China, by contrast, emphasizes data localization and cyber-sovereignty through a state-centric approach. For firms engaged in cross-border digital trade, this fragmentation can generate substantial compliance costs by requiring adherence to multiple regulatory regimes rather than a unified framework, thereby limiting potential efficiency gains.

Empirical evidence also suggests that the effectiveness of these governance frameworks is uneven. Digital provisions in trade agreements generally benefit high-income economies by reducing regulatory uncertainty for exporters. Their effects appear weaker in low-income economies, where such legal instruments often provide limited practical value (UNCTAD, 2024; World Bank, 2023). In developing countries, digital provisions frequently address issues such as source-code protection and cross-border data flows, whereas the primary constraints are often fiscal and structural. This divergence is particularly evident in digital taxation as developed economies seek to liberalize data flows, developing economies often struggle to capture revenue from large multinational digital firms operating within their markets.

This disparity raises an important question, “do digital trade rules effectively promote integration in developing regions?” The existence of a trade agreement does not guarantee the capacity to utilize it. We therefore test the marginal effect of digital provisions relative to the baseline effect of general trade agreements. Our gravity estimates reveal a counterintuitive result. While general trade agreements increase digital trade by approximately 33%, the addition of digital provisions generates only a modest marginal gain of about 5%. This suggests that, for CAREC economies, current digital provisions are not major drivers of market integration.

2.3. Regional and Developing Country Perspectives

Existing research on digital trade is heavily concentrated on East Asia, Europe, and the United States. For example, Zhang et al. (2024) examined digital integration in East Asian manufacturing hubs and Western service economies. In contrast, digital trade in developing regions such as CAREC remains comparatively understudied. This gap is important because the binding constraints facing Central Asia may differ fundamentally from those in digitally advanced economies. Razzaq et al. (2022) showed that although CAREC countries have improved basic internet access, substantial infrastructure deficits persist, particularly in landlocked countries such as Afghanistan and Tajikistan, where geography complicates broadband deployment.

These infrastructure deficits shape policy tradeoffs in developing economies. Recent evidence suggests that limited connectivity, rather than deficiencies in digital regulation, is the primary barrier to investment in Central Asia. The Digital Foreign Direct Investment Ecosystem report (2025) evaluates multiple dimensions of digital development, including infrastructure, promotion tools, and adoption metrics, and ranks digital infrastructure as the weakest area in the CAREC region, with an average score of 59.6 out of 100.³ Consequently, even where regulatory frameworks are modernized, high-bandwidth activities such as cloud computing and real-time data transmission remain constrained if adequate infrastructure is absent. This may help explain the substantial heterogeneity

³ <https://policycommons.net/artifacts/7941958/digital-fdi-ecosystem-in-the-carec-region-phase-ii/8852280/>

in digital trade across the region. Countries such as Kazakhstan and Georgia may derive greater benefits from digital provisions because they possess stronger digital connectivity, whereas countries with weaker infrastructure remain largely disconnected from digital value chains.

Most regional studies have relied on descriptive evidence to document connectivity gaps (Razzaq et al., 2022, 2023; Samad, 2025). We move beyond benchmarking by embedding infrastructure deficits within a structural gravity framework. Rather than ranking countries using composite indices, we estimate the partial-equilibrium elasticity of digital trade with respect to three dimensions of digital technology. Our counterfactual analysis quantifies the trade gains associated with closing infrastructure gaps. Specifically, we estimate that convergence to the CAREC median infrastructure level would generate approximately \$915 million in additional annual exports (95% CI: \$494–\$1,397 million). This approach translates normative policy objectives into measurable economic outcomes.

2.4. Methodological Approaches to Measuring Digital Trade

A persistent challenge in this literature is the conceptual ambiguity between goods and services in the digital economy. The traditional statistical distinction is increasingly obsolete. The 2023 OECD/World Trade Organization (WTO)/International Monetary Fund (IMF)/U.N. Conference on Trade and Development (UNCTAD) Handbook on Measuring Digital Trade⁴ represents a coordinated international effort to establish statistical standards, defining digital trade as “all international trade that is digitally ordered and/or digitally delivered.” Nonetheless, implementation challenges remain, particularly in distinguishing digitally ordered from digitally delivered trade.

Corporate-revenue approaches offer promising alternatives to traditional trade statistics. Stojkoski et al. (2024) employed machine learning techniques to analyze 2,502 firms across 189 countries, combining Orbis data, mobile-app analytics, and optimal transport algorithms. Their methodology addresses longstanding difficulties in capturing small-firm digital trade and Mode 3 commercial presence.

Gravity-model applications have also become more sophisticated. Blázquez et al. (2023) developed a two-stage framework that separates trade-flow prediction from network analysis, avoiding traditional challenges associated with network effects. However, most studies continue to treat digital trade as a single category, without testing whether determinants such as infrastructure and policy vary according to the degree of digital intensity.

We address this aggregation problem through a granular, multi-layered identification strategy. Rather than relying on a single proxy, we reconstruct the dependent variable using a layered classification derived from the OECD–WTO bilateral database (see Section 4.1). Specifically, we define Core Digital Trade as services for which digital delivery is effectively the only practical mode, including cloud computing and streaming services. We also construct a Broad Digital Trade measure that includes professional services, such as consulting and legal services, when remote delivery is involved. This distinction allows us to examine whether the elasticity of digital trade with respect to infrastructure increases with the degree of digital intensity embodied in the traded service. In doing so, we provide evidence on how the composition of digital trade responds to differences in digital connectivity.

⁴ See report page: <https://unctad.org/publication/handbook-measuring-digital-trade>

3. Empirical Methodology

To quantify the effects of digital technology on trade, we employ a structural gravity framework, which allows us to model digital infrastructure not merely as a control variable but as a direct determinant of bilateral trade costs (Linders and de Groot, 2006). Unlike traditional gravity specifications that rely primarily on physical distance and economic size, we treat digital connectivity as a variable trade friction that compresses the "virtual distance" between markets. This framework enables us to identify how improvements in the digital ecosystem, such as broadband quality, reduce the fixed costs of exporting and expand the range of services that can be traded digitally, while controlling for multilateral resistance effects.

Our core gravity model specification is given by

$$\text{DigitalTrade}_{ijt} = \exp \left\{ \beta_1 \text{DigitalComponent}_{ijt} + \beta_2 \text{DigitalInfra}_{ijt} + \beta_3 \text{DigitalPlat}_{ijt} + \beta_4 \text{PTA}_{ijt} + \beta_5 \text{PTA}_{ijt} \times \text{DP}_{ijt} + \mu_{it} + v_{jt} + \rho_{ij} \right\} + \varepsilon_{ijt},$$

where $\text{DigitalTrade}_{ijt}$ represents digital product exports from country i to country j in year t ; $\text{BilateralDigitalTech}_{ijt}$ is a vector of bilateral digital technology measures, including digital components, digital infrastructure, and digital platforms; PTA_{ijt} is a binary indicator equal to 1 when a PTA is in force and 0 otherwise, constructed using the Design of Trade Agreements (DESTA) and the WTO Regional Trade Agreements database to capture the effects of general trade liberalization; DP_{ijt} is a binary indicator for PTAs containing specific digital commerce provisions (e.g., data-flow commitments, consumer protection measures, and paperless trading provisions) constructed from the Trade Agreements Provisions on Electronic-Commerce and Data (TAPED) database developed by Burri and Polanco (2020); μ_{it} represents exporter-year fixed effects that capture all time-varying exporter-specific factors; v_{jt} represents importer-year fixed effects that capture all time-varying importer-specific factors; ρ_{ij} represents country-pair fixed effects that capture all time-invariant bilateral factors; and ε_{ijt} is the error term.

We expect positive coefficients for the bilateral digital technology measures ($\beta_{1,2,3} > 0$), indicating that higher levels of digital technology facilitate greater digital trade between countries. The relative magnitudes of these coefficients provide evidence on the importance of different dimensions of digital technology in promoting digital trade. Similarly, we expect positive coefficients for variables capturing digital openness and digital provisions in trade agreements, as both are intended to reduce barriers to digital trade.

The model is estimated using Poisson pseudo-maximum likelihood (PPML), as recommended by Santos Silva and Tenreyro (2006). PPML offers several advantages over alternative estimators. It accommodates zero trade flows, which are common in bilateral trade data, and provides robust estimates in the presence of heteroskedasticity.

4. Data and Measurement

4.1 Digital Trade Data

The primary data source for this study was the OECD–WTO Balanced Trade in Services (BaTIS) dataset, which is widely used in the trade literature and provides bilateral services trade flows for 190 countries from 2005 to 2021. This dataset enabled us to construct the tiered set of dependent variables required for our empirical framework.

Our baseline dependent variable is Broad Digital Trade, which captures the broadest definition of digital trade. It includes all services that can be delivered digitally, ranging from telecommunications and software to digitally mediated professional services. This measure minimizes the risk of overlooking digital trade activity that may otherwise be embedded within conventionally defined non-digital trade.

We also employed a narrower measure, Core Digital Trade, which is limited to services for which digital delivery is the primary or exclusive mode of trade. This category includes cloud computing, software downloads, and streaming services. By excluding services that may still require some face-to-face interaction, such as certain consulting activities, this measure allows us to assess whether infrastructure effects remain consistent in more strictly digital sectors. Finally, we use Digitally Deliverable Services as an upper-bound measure. This definition encompasses professional, entertainment, and educational services that can potentially be delivered online, regardless of the extent to which digital delivery currently dominates actual transactions.

In Central Asia, data availability remains a significant challenge for measuring digital trade. The BaTIS dataset contains notable gaps in the early years of the sample period. To address this issue, we supplement the data with national statistics and WTO TiSMoS data where necessary. In all cases, we restrict the analysis to Mode 1 (cross-border supply) flows to align with the conceptual logic underlying our digital infrastructure measures.

4.2 Digital Technology Measures

We examined three dimensions of digital technology that are relevant to digital trade. Data for each dimension were collected from multiple sources:

- Digital infrastructure—Fixed broadband penetration, fixed telephone penetration, and mobile telephone penetration obtained from WDIs.
- Digital components—Robot stock data from the International Federation of Robotics. We used robot stock as a proxy for the digital components layer because industrial robots represent digitally controlled physical capital that supports automated production and logistics, which increasingly underpin the processing, warehousing, and fulfillment activities associated with digital service delivery. This approach follows Acemoglu and Restrepo (2020), who identified robots as an appropriate measure of automation capital embodied in production. We acknowledge that robot stock is more closely linked to manufacturing than to services trade. Section 5.1 discusses the implications of this measurement choice, and we therefore interpreted the digital components results as exploratory rather than primary.
- Digital platforms—Mobile broadband activity rates and subscriber network traffic obtained from the International Telecommunication Union. These indicators capture the intensity of mobile internet use rather than simple access. We interpret them as proxies for platform ecosystem depth, whereby countries with higher mobile data traffic tend to have denser networks of digital applications, e-commerce platforms, and cloud-based services through which cross-border digital trade occurs. Because these indicators primarily reflect domestic usage intensity rather than direct international openness, the platform variable should be interpreted as a measure of the digital economy’s absorptive capacity for cross-border services.

We applied the entropy method to construct a composite digital technology index for each country. Bilateral measures were then calculated using the geometric mean:

$$DTI_{ijt} = \sqrt{DT_{it} \times DT_{jt}}$$

where $DT_{B_{it}}$ and $DT_{B_{jt}}$ represent the exporter and importer digital technology indices, respectively. The geometric mean is commonly used in the gravity literature (e.g., Herman and Oliver, 2023) because it satisfies the symmetry of bilateral trade costs and reflects the fact that digital exchange requires connectivity on both sides of a transaction. It also provides intuitive interpretation: if one country has no digital infrastructure, bilateral digital capacity is effectively zero regardless of the infrastructure level of its trading partner.

A natural question is whether exporter and importer infrastructure should receive equal weight. In our gravity specification, all time-varying exporter characteristics, including unilateral digital infrastructure, were absorbed by exporter-year fixed effects, while all importer-specific characteristics were absorbed by importer-year fixed effects. As a result, variables constructed solely from exporter or importer characteristics remained perfectly collinear with these fixed effects and contain no identifying variation. The bilateral geometric mean is therefore not simply a modeling preference, but the only specification identified in the presence of full exporter-year and importer-year fixed effects. It captures the within-pair, within-year variation in joint connectivity that remains after unilateral effects have been absorbed. We verified this formally: replacing the geometric mean with exporter-only or importer-only proxies results in perfect collinearity and automatic omission by the estimator, confirming that separate exporter-only or importer-only tests are infeasible in this framework.⁵

4.3 Descriptive Analysis

Table 1 reports summary statistics for the main variables. The infrastructure sample (N = 622,378) covered 73 countries, including all 11 CAREC members, over the 2005–2021 period and represents more than 95% of global digital services trade. The sample exhibits substantial variation in economic development: 54.7% of country-pair-year observations involve at least one low- or lower-middle-income country,⁶ while 10.2% involve at least one CAREC member.

The three digital trade measures displayed considerable variation and highly skewed distributions. Broad Digital Trade, our primary dependent variable, averaged \$33.7M per country-pair-year, with a standard deviation of \$483.7M. The maximum bilateral flow reached \$73.6B, while many country pairs reported zero digital trade, justifying the use of PPML estimation. Core Digital Trade (\$18.8M mean) and Digitally Deliverable Services (\$61.5M mean) exhibited similar patterns. Broad Digital Trade represented ~28% of total bilateral services trade in the sample, averaging \$122.2M.

Trade policy variables indicated that country pairs average 0.47 PTAs (SD = 2.62; max = 31), with some pairs covered by multiple overlapping agreements. Digital provisions appeared in only 8.7% of country-pair-year observations, reflecting their relatively recent emergence in trade agreements. This limited prevalence may contribute to less precise estimates of their effects.

The digital technology measures were available jointly only for a restricted sample (N = 10,203). Within this sample, digital infrastructure had a mean of 0.252 (SD = 0.094), digital components a mean of 0.013 (SD = 0.040), and Digital Platform Openness a mean of 0.680 (SD = 0.095). The reduction from 622,378 to 10,203 observations reflects the limited availability of components and platform data, which were concentrated in recent years and higher-income economies. This constraint has important implications for interpretation. The restricted sample was not a random

⁵ The correlation between the exporter proxy and the bilateral index ($r=0.692$) and the importer proxy and the bilateral index ($r=0.693$) were nearly identical, providing further evidence that both sides contributed symmetrically to the bilateral measure and that equal weighting was not an arbitrary restriction.

⁶ LIC/LMIC, using the World Bank FY2021 classification.

subset of the full population but is systematically skewed toward wealthier, more recent, and more digitally advanced country pairs. Consequently, direct comparisons of coefficient estimate across columns may be misleading if interpreted as representing the same underlying population.⁷

Table 1: Summary of key variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Broad Digital Trade	622,378	33.6901	483.6857	0.0000	73,559.9922
Core Digital Trade	622,378	18.8080	293.9653	0.0000	62,349.0898
Digitally Deliverable Services	622,378	61.5311	821.4455	0.0000	128,287.8750
ict_services	622,378	9.7198	125.6612	0.0000	14,577.3271
total_services	622,378	122.2470	1,246.8327	0.0000	130,647.4375
PTA (count)	622,378	0.4744	2.6151	0.0000	31.0000
Digital Provisions (dummy)	622,378	0.0873	0.2823	0.0000	1.0000
Digital Components	10,203	0.0132	0.0396	0.0000	0.7115
Digital Infrastructure	10,203	0.2518	0.0939	0.0218	0.4848
Digital Platform	10,203	0.6799	0.0948	0.0000	0.9237
Openness					

Notes: Summary statistics for the key variables used in the gravity-model analysis. The sample corresponds to the infrastructure specification reported in Column 2 of Table 2 and includes 622,378 country-pair-year observations covering 73 countries during 2005–2021. All trade variables were measured in USD millions. Broad Digital Trade is the primary dependent variable and captures digitally enabled services that can be delivered remotely through digital networks, following the classification of Kong et al. (2024). Core Digital Trade applies a narrower definition restricted to inherently digital services. Digitally Deliverable Services adopts the broadest definition, encompassing all services that can potentially be delivered digitally. ICT Services include telecommunications, computer, and information services, while Total Services represents overall bilateral services trade. PTA (count) measures the number of PTAs between country pairs. Digital Provisions is a binary indicator equal to one when a PTA contains digital trade provisions and zero otherwise. Digital Components, digital infrastructure, and Digital Platform Openness were normalized to range from 0 to 1, with higher values indicating greater levels of development. Statistics for these variables are reported for the restricted sample (N = 10,203) in which all three measures were jointly available.

5. Results

This section presents the main empirical findings from the gravity-model analysis. We begin with baseline estimates of the relationship between digital technology and trade flows, then assess robustness using alternative dependent-variable definitions, and finally examine the unexpected negative interaction between PTAs and digital provisions.

⁷ To make this concrete, we re-estimated the infrastructure-only specification (Column 2) on the restricted N=10,203 sample: the coefficient fell to $\beta=1.422$ (SE=1.371, p=0.300), becoming statistically insignificant. The loss of precision was therefore driven by sample attrition. That is, the restricted sample did not contain enough variation to precisely identify the infrastructure elasticity rather than by multicollinearity with the components and platforms variables. This motivated us to treat Column 2 (N=622,378) as the primary specification for all counterfactual simulations and Column 5 as an indicative multidimensional result whose coefficients should not be directly compared with Column 2 in magnitude.

5.1 Baseline Gravity Model Estimates

Table 2 reports the baseline gravity model estimates, progressively incorporating digital technology measures to evaluate their individual and joint associations with bilateral digital services trade. All specifications were estimated using PPML with exporter-year and importer-year fixed effects, which controlled for time-varying multilateral resistance terms and country-specific determinants of trade (Anderson and van Wincoop, 2003; Santos Silva and Tenreyro, 2006). Country-pair fixed-effects-absorbed time-invariant bilateral characteristics, such as geography, cultural proximity, and institutional similarity, while international border-year fixed effects captured time-varying international trade costs (Bergstrand et al., 2015). Standard errors were clustered at the country-pair level to account for potential serial correlation in bilateral trade flows.

The results reveal a clear hierarchy among the estimated correlates of digital trade. We began by benchmarking the role of trade policy in Column (1). Standard PTAs are associated with a robust trade-creation effect of approximately 33% ($\beta = 0.284$). In contrast, the interaction term capturing the addition of specific digital provisions is negative and statistically significant ($\beta = -0.235$), implying a marginal benefit of only about 5%. This finding suggests that, during 2005–2021, the liberalization embodied in digital trade provisions added relatively little beyond the broader market-access benefits associated with standard trade agreements.

The inclusion of digital infrastructure in Column (2) substantially alters the relative magnitudes of the estimated effects. The infrastructure elasticity ($\beta = 3.769$) is considerably larger than the policy coefficients. A one-standard-deviation increase in bilateral infrastructure connectivity is associated with a 43% increase in digital trade volume, on average across country pairs in the sample. Moving from the 25th to the 75th percentile of infrastructure quality—a plausible medium-term development target—is associated with a 55% increase in trade volume. Importantly, the PTA coefficient remains largely unchanged ($\beta = 0.264$) after infrastructure is introduced. This stability suggests that infrastructure connectivity and trade policy capture distinct dimensions of bilateral trade costs, and that infrastructure explains a substantial portion of the variation in digital trade beyond what can be attributed to legal harmonization alone. These estimates should nevertheless be interpreted as conditional correlations derived from panel variation. Although the extensive fixed-effects structure mitigated many sources of confounding, unobserved bilateral factors correlated with both infrastructure and trade may have contributed to the observed relationships.

Table 2: Impact of digital technologies on digital trade

	Dependent Variable: Digital Trade Measure 1				
	(1)	(2)	(3)	(4)	(5)
PTA	0.2839*** (0.0544)	0.2636*** (0.0536)	0.2825*** (0.0577)	0.2671*** (0.0719)	0.3234*** (0.0832)
PTA_x_Digital Provisions	-0.2346*** (0.0533)	-0.2148*** (0.0524)	-0.2258*** (0.0566)	-0.2271*** (0.0714)	-0.2791*** (0.0822)
Digital Infrastructure		3.7692*** (0.8101)			2.0053 (1.3554)
Digital Components			1.2754** (0.5573)		0.9751** (0.4929)
Digital Platforms				7.5075*** (2.5959)	10.0819*** (3.1639)

Exporter-year FE	Yes	Yes	Yes	Yes	Yes
Importer-year FE	Yes	Yes	Yes	Yes	Yes
Country-pair FE	Yes	Yes	Yes	Yes	Yes
R ²	0.930	0.931	0.915	0.935	0.919
Observations	66,1675	622,378	80,520	135,466	10,203

Notes: Each column incorporates an expanded set of digital technology controls and was estimated using the largest sample available for the corresponding variables. Column (1) includes only PTA variables (N = 661,675). Column (2) adds digital infrastructure (N = 622,378). Column (3) adds digital components only (N = 80,520). Column (4) adds Digital Platform Openness only (N = 135,466). Column (5) includes all three digital technology measures jointly (N = 10,203). The progressive decline in sample size reflects the more limited country and year coverage of the Components and Platform datasets. Consequently, coefficient comparisons across columns should be interpreted with caution because the underlying samples differ. Re-estimating the infrastructure-only specification on the restricted N = 10,203 sample yields $\beta = 1.422$ (SE = 1.371, $p = 0.300$), indicating that the loss of precision in the infrastructure coefficient reported in Column (5) is driven by sample attrition rather than multicollinearity. All models are estimated using PPML (ppmlhdf) with exporter-year and importer-year fixed effects. Standard errors clustered at the country-pair level are reported in parentheses. The dependent variable in all specifications is Broad Digital Trade, measured in millions of U.S. dollars. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

The robustness of these relationships is examined in Columns (3)–(5), which introduces alternative technology measures capturing digital components and platform ecosystems. Although data limitations substantially reduced the sample size, the overall pattern remains unchanged. Digital Components retains a positive and statistically significant coefficient ($\beta = 1.275$), indicating that greater availability of automation capital is associated with higher service exports. This finding is consistent with the view that hardware-based productive capacity supports digital service delivery, although the result should be interpreted cautiously given the measurement limitations discussed in Section 4.2.

Even in the most demanding specification (Column 5), where all technology measures are estimated jointly on the restricted sample (N = 10,203), the infrastructure coefficient remains economically large ($\beta = 2.005$), although it no longer reaches conventional levels of statistical significance. The stability of the trade policy coefficients across all five specifications (0.26–0.32) further reinforces the central pattern. Across specifications, the estimated association between infrastructure and digital trade is substantially larger than the marginal association attributable to digital trade provisions. To assess whether this elasticity extends to the CAREC context, we re-estimated the Column (2) specification across income-group subsamples and for CAREC-involved country pairs. These results are reported in Appendix Table A2 and discussed in Section 6.2.

5.2 Robustness: Alternative Dependent Variables

Table 3 evaluates whether the core findings are robust to alternative definitions of digital trade. Specifically, we applied the full specification from Table 2, Column (5), which includes all three digital technology measures, to five alternative dependent variables ranging from the broadest category (Total Services) to the narrowest and most technology-intensive category (ICT Services).⁸

⁸ Interpretation of the digital components and Digital Platform coefficients should be read in conjunction with the measurement caveats noted in Section 4.2: robot stock is a broad proxy for automation capital and is more directly

The results reveal meaningful heterogeneity consistent with theoretical expectations. Although digital infrastructure is positively associated with trade across all specifications, the magnitude of the effect increases with the digital intensity of the traded activity. The estimated elasticity is smallest for Total Services (Column 5, $\beta = 0.435$), which included traditional service transactions that are less dependent on bandwidth and digital connectivity. As the definition narrows to Core Digital Trade (Column (2), $\beta = 1.387$) and Broad Digital Trade (Column (1), $\beta = 0.975$), the coefficient increases substantially and becomes highly significant ($p < 0.01$). This pattern supports our identification strategy. If the infrastructure index merely captured general economic development, its effects would be expected to remain relatively uniform across service categories. Instead, larger elasticities for more digitally intensive activities are consistent with the interpretation that infrastructure reduces transmission-specific trade frictions.

The findings regarding digital trade provisions are equally robust. Across all five dependent variables, the PTA coefficient remains within a relatively narrow range (0.24–0.39), while the interaction term for digital provisions remains consistently negative, ranging from -0.202 to -0.339 . This stability suggests that the limited marginal contribution of digital trade chapters is a persistent feature of the data rather than an artifact of a particular trade definition. Whether the dependent variable captures broadly defined professional services or narrowly defined digital products, the estimated association between physical infrastructure and bilateral trade consistently exceeds that associated with legal harmonization through digital trade provisions.

Table 3: Impact of digital technologies on digital trade: Alternative measures

Dependent Variable: Alternative Measures of Digital Trade					
	(1)	(2)	(3)	(4)	(5)
PTA	0.3234*** (0.0832)	0.2405** (0.1024)	0.3373*** (0.0766)	0.3531*** (0.0986)	0.3898*** (0.0844)
PTA_x_Digital Provisions	-0.2791*** (0.0822)	-0.2029** (0.1021)	-0.2946*** (0.0753)	-0.3119*** (0.0978)	-0.3389*** (0.0839)
Digital Infrastructure	0.9751** (0.4929)	1.3867*** (0.5337)	0.5714 (0.4877)	0.4786 (0.5059)	0.4350 (0.5357)
Digital Components	2.0053 (1.3554)	1.0369 (1.5093)	1.7178 (1.2304)	2.5811** (1.2480)	1.9870* (1.1535)
Digital Platforms	10.0819*** (3.1639)	10.8625*** (3.9095)	6.0491** (2.9905)	11.0813*** (3.2607)	5.1099** (2.4253)
Exporter-year FE	Yes	Yes	Yes	Yes	Yes
Importer-year FE	Yes	Yes	Yes	Yes	Yes
Country-pair FE	Yes	Yes	Yes	Yes	Yes

associated with manufacturing than services; the platform variable captures domestic usage intensity, which is an imperfect proxy for cross-border digital trade openness.

G	0.930	0.931	0.915	0.935	0.919
Observations	661,675	622,378	80,520	135,466	10,203

Notes: All regressions include the full set of digital technology measures—digital components, digital infrastructure, and Digital Platforms—estimated using the restricted sample for which all three measures are available. Models were estimated using PPML with exporter- and importer-year fixed effects. Standard errors clustered at the country-pair level are reported in parentheses. The dependent variables are (1) Broad Digital Trade, (2) Core Digital Trade, (3) Digitally Deliverable Services, (4) ICT Services, and (5) Total Services, all measured in USD millions. The consistency of coefficient signs and significance levels across alternative trade definitions provides evidence of the robustness of the estimated relationships. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

5.3 Digital Provisions Effects

Our analysis reveals a consistent empirical pattern: although general trade agreements are associated with higher levels of digital trade, the marginal effect of adding specific digital provisions is small and negative across all specifications. Several interpretations are consistent with this result, although the available data do not allow us to distinguish definitively among them.

One explanation is an implementation gap. Unlike traditional tariff reductions, which are relatively straightforward to administer, digital trade commitments (e.g., cross-border data-flow guarantees and paperless trading standards) require sophisticated domestic regulatory and institutional capacity. In many CAREC economies, the institutions needed to implement these provisions, including cybersecurity agencies and digital customs systems, remain underdeveloped or under-resourced (Razzaq et al., 2022, 2023). Under this interpretation, digital provisions function more as aspirational commitments than binding constraints, and their limited marginal effect reflects a gap between legal commitments and institutional capacity.

A second explanation is selection. Countries that negotiate digital chapters may do so precisely because their regulatory environments are complex or because existing trade relationships face significant barriers. If agreements containing digital provisions are systematically concentrated among countries with distinct characteristics (larger development gaps or more recent treaty negotiations), the negative coefficient may reflect underlying compositional differences rather than a causal effect of the provisions themselves. In the absence of a credible instrument for digital-chapter adoption, we cannot disentangle these competing explanations.

A third possibility concerns negotiating priorities. Agreements that include digital chapters may devote relatively less attention to traditional services liberalization, resulting in a lower overall level of trade-facilitating content. Under this interpretation, the negative interaction reflects a substitution in negotiating emphasis rather than a direct effect on trade outcomes.

Accordingly, we interpreted the negative coefficient as an informative empirical pattern rather than evidence that digital trade provisions are ineffective or harmful. The most defensible policy conclusion is that, within our sample, connectivity infrastructure appears to be a more important correlate of digital trade integration than regulatory provisions. Digital rules may provide limited benefits when the underlying infrastructure required to support digital transactions remains inadequate. From this perspective, infrastructure investment should precede, rather than replace, efforts toward regulatory harmonization.

6. Counterfactual Analysis: Digital Infrastructure Investment Scenarios

We next used the structural gravity framework to translate the estimated elasticities into partial-equilibrium projections of trade gains. Having established that physical connectivity is the strongest correlate of digital trade across all specifications, we simulated how targeted improvements in digital infrastructure would affect bilateral trade flows within the CAREC region. These simulations modeled infrastructure improvements as reductions in bilateral trade costs proportional to the estimated infrastructure elasticity. They were calibrated using observed infrastructure deficits and should be interpreted as indicative projections conditional on the estimated relationship between infrastructure and trade, rather than as causal forecasts.

6.1 Current State of Digital Infrastructure and Trade

The baseline data reveal a region characterized by substantial digital disparities. As shown in Table 4, infrastructure capacity varies markedly across CAREC economies. Georgia, the regional leader, records an infrastructure index of 0.246, nearly four times that of Afghanistan, the lowest-ranked country at 0.065. This heterogeneity highlights that CAREC does not operate as a uniform digital economy. A group of countries, including Kazakhstan and Uzbekistan, has already reached or exceeded the ASEAN benchmark, demonstrating that advanced digital connectivity is attainable within the Central Asian context.

Furthermore, five countries remain below the regional median. The economic implications of these infrastructure gaps are evident in the export data. While the average ASEAN economy exports more than \$8.4B in digital services annually, the average CAREC member exports only \$469M. This 18-fold difference suggests that, within our sample, infrastructure is the most important quantitative correlate of participation in digital markets among lower-income CAREC economies. The counterfactual exercises that follow therefore estimate the potential gains associated with alleviating this infrastructure constraint.

Table 4: Digital Infrastructure and Exports in CAREC countries (2021)

Country	Digital Infrastructure Index	Digital Exports (\$M)	Gap to ASEAN Median
Afghanistan	0.065	843	-0.120
Azerbaijan	0.226	533	+0.041
Georgia	0.246	392	+0.061
Kazakhstan	0.203	599	+0.018
Kyrgyz Republic	0.131	94	-0.054
Mongolia	0.190	76	+0.005
Pakistan	0.090	1,401	-0.095
Tajikistan	0.106	135	-0.079
Turkmenistan	0.141	185	-0.044
Uzbekistan	0.233	431	+0.048
CAREC Median	0.166	469	-0.019

Country	Digital Infrastructure Index	Digital Exports (\$M)	Gap to ASEAN Median
ASEAN Median	0.185	8,441	—

Note: The digital infrastructure index was normalized to a 0–1 scale. Digital exports include digital goods, productized services, and intermediation fees, following the classification of Stojkoski et al. (2024). The gap to the ASEAN median was calculated as the difference between each country’s infrastructure index and the ASEAN median value of 0.185.

6.2 Counterfactual Methodology

To quantify these potential gains, we employed a structural gravity simulation that treats infrastructure improvements as direct shocks to bilateral trade costs. Following the framework of Anderson and van Wincoop (2003), we modeled the digital ecosystem as a variable trade friction, whereby improvements in connectivity reduce the "iceberg" costs of delivering services across borders. Formally, the reduction in trade costs resulting from a policy intervention is calculated as

$$\frac{\tau_{new}}{\tau_{old}} = \exp\left(-\frac{\beta \cdot \Delta}{\sigma - 1}\right),$$

where $\beta_{infra} = 3.769$ is the preferred infrastructure elasticity estimate from Column (2) of Table 2—the infrastructure-only specification estimated on the full sample of 622,378 country-pair-year observations (SE = 0.810, $p < 0.001$).⁹ We prefer this specification to the full three-variable model (Column 5) for two reasons. First, it maximizes sample coverage and provides the most precise estimate of the infrastructure elasticity. Second, the infrastructure coefficient in the full specification ($\beta = 2.005$, SE = 1.355, $p = 0.139$) becomes statistically insignificant because the sample contracts to only 10,203 observations, making it unsuitable as the basis for welfare projections.

A useful property of the constant elasticity of substitution framework is that the percentage change in trade volumes reported in Tables 5 and 6 simplifies to $\exp(\beta \times \Delta) - 1$ and is therefore independent of σ . The role of σ is instead to translate trade-volume changes into welfare gains through the relationship $W \approx \Delta X / (\sigma - 1)$, following Arkolakis, Costinot, and Rodríguez-Clare (2012). In this setting, the simulation captures the supply-side effect of improved connectivity by quantifying how much less costly digital trade becomes as bandwidth constraints are relaxed.

One concern with applying the full-sample elasticity to CAREC-specific counterfactuals is that the estimate pools economies at very different levels of development. To address this issue, we re-estimated the Column (2) specification across income-group subsamples using World Bank FY2021 classifications (Appendix Table A2). The estimated infrastructure elasticity is $\beta = 3.047$ (SE = 1.453, $p = 0.036$) for low-income country (LIC)/lower-middle income country (LMIC) country pairs and $\beta = 4.784$ (SE = 1.866, $p = 0.010$) for HIC pairs. For CAREC-involved country pairs, the elasticity rises to $\beta = 6.873$ (SE = 2.018, $p = 0.001$). A formal interaction test between infrastructure and the LIC/LMIC indicator is statistically insignificant ($p = 0.332$), indicating that we cannot reject equality of elasticities across income groups. Importantly, the CAREC-specific estimate exceeds the full-sample baseline, implying that simulations based on $\beta = 3.769$ are conservative for the CAREC region. We

⁹ We noted that a CAREC-specific subsample regression yielded a larger point estimate of $\beta = 6.873$ (SE = 2.018, $p = 0.001$, $N = 63,457$), suggesting the full-sample coefficient used here produces conservative welfare projections for the CAREC region; a sensitivity check using this CAREC-specific elasticity is included in Appendix Table A3.

therefore retained the full-sample estimate due to its greater precision while reporting CAREC-specific welfare sensitivities in Appendix Table A3.¹⁰

To translate reductions in trade costs into trade flows, we adopted a standard CES demand structure in which trade responds to cost changes with an elasticity of $1 - \sigma$. Using $\sigma = 7$, consistent with Head and Mayer (2014), a 1% reduction in digital trade costs corresponds to a 6% increase in export value.

To reflect parameter uncertainty, we propagated the standard error of β_{infra} through the simulation formula to generate 95% confidence intervals for all projected export gains. These intervals are reported alongside the central estimates in Tables 5 and 6. We also report welfare sensitivities for $\sigma \in \{5, 7, 9, 11\}$, representing the range of plausible services-trade elasticities identified by Head and Mayer (2014), in Appendix Table A1.

These projections should be interpreted as partial-equilibrium estimates. Because the analysis abstracted from general-equilibrium mechanisms, including multilateral resistance adjustments, income multipliers, and productivity spillovers. Hence, the reported gains may either understate or overstate total welfare effects. By focusing exclusively on the direct channel, we isolated the implications of the estimated infrastructure elasticity and avoided imposing additional assumptions regarding price-index adjustments or broader equilibrium responses. Although such mechanisms would likely increase the total gains from connectivity improvements, the present approach ensured that the projections remain closely tied to the empirical estimates obtained from the gravity model.

6.3 Scenario 1: Regional Convergence to CAREC Median

The regional convergence scenario represents a feasible short- to medium-term policy objective that could be achieved within 3 to 5 years through coordinated regional cooperation and knowledge sharing. The scenario targets the five CAREC countries that remain below the regional median infrastructure level (0.166): Afghanistan, the Kyrgyz Republic, Pakistan, Tajikistan, and Turkmenistan. Required improvements range from 0.025 index points in Turkmenistan to 0.101 points in Afghanistan. These magnitudes are broadly consistent with historical examples of rapid digital infrastructure expansion in comparable settings (Cariolle, 2021; Hjort and Poulsen, 2019).

Table 5 reports the results for Scenario 1 using the preferred infrastructure elasticity ($\beta = 3.769$, $SE = 0.810$). The simulated infrastructure improvements reduced trade costs by between 1.64% in Turkmenistan and 6.60% in Afghanistan, generating corresponding increases in trade volumes ranging from 9.7% to 46.2%. These differences reflect both the size of each country's infrastructure gap and its initial export base. Afghanistan and Pakistan account for 84% of exports among the below-median countries and capture approximately 93% of the projected gains.

At the regional level, the simulation yields an estimated increase of \$915M in annual digital services exports (95% CI: \$494M–\$1,397M). The relatively wide confidence interval reflects uncertainty surrounding the infrastructure elasticity estimate. Accordingly, the result should be interpreted as an indicative order-of-magnitude projection rather than a precise forecast.

¹⁰ The CAREC-specific estimate was substantially less precisely estimated than the full-sample baseline ($SE = 2.018$ vs. $SE = 0.810$), and its 95% confidence interval spanned 2.918 to 10.828; the figures in Appendix Table A3 should therefore be interpreted as an illustrative upper bound rather than a refined central estimate.

Table 5: Scenario 1 results—Regional convergence to CAREC median

Country	Current Infrastructure	Improvement Needed	Trade Cost Reduction (%)	Trade Increase (%)	Add. Exports (\$M)	95% CI (\$M)
Afghanistan	0.065	0.101	6.60	46.2	389.0	[207.0, 602.5]
Kyrgyz Republic	0.131	0.035	2.39	14.1	13.2	[7.5, 19.4]
Pakistan	0.090	0.076	4.97	32.9	461.0	[250.7, 698.1]
Tajikistan	0.106	0.060	3.95	25.4	34.1	[18.8, 51.0]
Turkmenistan	0.141	0.025	1.64	9.7	18.0	[10.2, 26.1]
Weighted Average	—	0.059	3.91	34.9	915	[494–1,397]

Note: The target infrastructure level is the CAREC median value of 0.166. Trade cost reductions were calculated using the estimated infrastructure elasticity from Column (2) of Table 2 ($\beta = 3.769$, $SE = 0.810$, $p < 0.001$; $N = 622,378$). Under the CES framework, percentage changes in trade volumes are independent of σ and simplify to $\exp(\beta \times \Delta) - 1$. The 95% confidence intervals were obtained by propagating the standard error of β through the simulation formula. Weighted averages were calculated using baseline export values as weights. The central estimate of total additional annual digital services exports is \$915M, with a 95% confidence interval of \$494M–\$1,397M.

6.4 Scenario 2: Convergence to ASEAN Benchmark

While the regional convergence scenario addresses disparities within CAREC, it may still leave the region operating below internationally competitive levels of digital connectivity. To evaluate the potential gains from a more ambitious modernization strategy, our second counterfactual imposed an external benchmark by raising all CAREC economies to the ASEAN median infrastructure level (0.185). This threshold reflects the level of connectivity required to participate effectively in broader Asian digital value chains rather than merely facilitating trade within Central Asia.

The results presented in Table 6 highlight the uneven distribution of potential gains across the region. Because Azerbaijan, Georgia, Kazakhstan, Mongolia, and Uzbekistan already exceed the ASEAN benchmark, the simulated improvements are concentrated entirely among the region's digitally lagging economies. For these countries, the required adjustments were substantial. Afghanistan, for example, would need to increase its infrastructure index by 0.120 points, nearly doubling its current level. However, the projected returns are correspondingly larger. The model predicted trade-volume increases of 57.3% for Afghanistan and 43.0% for Pakistan, substantially exceeding the gains generated under the regional convergence scenario.

Aggregating the bilateral effects reveals the additional export potential associated with achieving the higher benchmark. The ASEAN convergence scenario was estimated to generate approximately \$1,186 million in additional annual digital services exports (95% CI: \$631M–\$1,841M), representing a 30% increase relative to the central estimate under the regional convergence scenario. This pattern is consistent with the possibility that higher levels of connectivity unlock access to more bandwidth-

intensive activities, such as cloud computing and real-time data transmission. However, this interpretation should be viewed cautiously because the CES framework employed here assumed a constant elasticity and did not explicitly model threshold effects or other nonlinearities. As with Scenario 1, these estimates should be interpreted as indicative order-of-magnitude projections rather than precise forecasts, given the uncertainty surrounding the underlying infrastructure elasticity.

Table 6: Scenario 2 results—ASEAN benchmark convergence

Country	Current Infrastructure	Improvement Needed	Trade Cost Reduction (%)	Trade Increase (%)	Add. Exports (\$M)	95% CI (\$M)
Afghanistan	0.065	0.120	7.85	57.3	482.4	[252.4, 760.8]
Kyrgyz Republic	0.131	0.054	3.58	22.8	21.4	[11.8, 31.8]
Pakistan	0.090	0.095	6.25	43.0	602.2	[322.1, 927.9]
Tajikistan	0.106	0.079	5.21	34.9	46.9	[25.4, 71.3]
Turkmenistan	0.141	0.044	2.91	18.0	33.4	[18.7, 49.3]
Weighted Average	-	0.079	-	-	1,186	[631–1,841]

Note: The target infrastructure level is the ASEAN median value of 0.185. Five CAREC countries—Azerbaijan, Georgia, Kazakhstan, Mongolia, and Uzbekistan—already met or exceeded this benchmark and therefore required no simulated adjustment. Trade cost reductions were calculated using the estimated infrastructure elasticity from Column (2) of Table 2 ($\beta = 3.769$, SE = 0.810, $p < 0.001$; N = 622,378). Under the CES framework, percentage changes in trade volumes are independent of σ and simplify to $\exp(\beta \times \Delta) - 1$. The 95% confidence intervals were obtained by propagating the standard error of β through the simulation formula. The central estimate of additional annual digital services exports is \$1,186M, with a 95% confidence interval of \$631M–\$1,841M.

7. Policy Implications and Conclusion

The asymmetry in the counterfactual results suggests that a uniform approach to digital integration is unlikely to be effective given the region’s uneven infrastructure endowments. Instead, the evidence supports a sequenced strategy that prioritizes physical connectivity before regulatory harmonization.

An effective policy approach would involve two stages. The immediate priority should be a regional convergence initiative focused on raising the connectivity floor rather than pushing countries toward the frontier. Our simulations indicate that bringing the five lagging economies—Afghanistan, the Kyrgyz Republic, Pakistan, Tajikistan, and Turkmenistan—to the regional median infrastructure level would generate substantial returns while requiring comparatively modest investment. Once this baseline is established, policymakers can pursue a second phase centered on achieving higher

connectivity benchmarks, such as the ASEAN median. This sequencing reduces the risk that regulatory ambitions outpace the physical capacity needed to support digital transactions.

Resource allocation should also reflect the concentration of projected gains. Afghanistan and Pakistan account for more than 90% of the gains in our central simulation because they combine large infrastructure deficits with relatively large export bases. This concentration is directionally robust, reflecting the fact that these are the two most populous below-median economies with the greatest potential for improvement. However, the magnitude should be interpreted cautiously. As noted in Section 4.1, services-trade data for both countries are supplemented using national statistics and WTO TiSMoS sources. In particular, Afghanistan's reported digital services exports of \$843 million may include transit and re-export activities that are difficult to attribute precisely. Nevertheless, expanding digital infrastructure in these large markets remains central to any regional integration strategy.

The region's internal heterogeneity also presents an opportunity. CAREC's digital leaders—Georgia, Kazakhstan, and Uzbekistan—effectively function as a regional technology club. Rather than relying exclusively on external technical assistance, policymakers could leverage the experience of these countries through South–South knowledge-transfer mechanisms. Drawing on the institutional experience of successful reformers may provide a lower-cost and more contextually relevant pathway for strengthening digital capacity in lagging economies.

This paper reexamines the determinants of digital trade integration using the CAREC region as a setting in which to evaluate the relative importance of "hard" infrastructure and "soft" trade policy. By constructing novel bilateral technology measures and incorporating them into a structural gravity framework, we identify three empirical patterns with important policy implications.

First, physical infrastructure emerges as the strongest correlate of digital trade in our data. The estimated elasticity of trade with respect to digital infrastructure substantially exceeds the estimated marginal effect of digital trade provisions across all specifications and dependent-variable definitions. This pattern is consistent with the view that bandwidth constraints represent a more binding trade cost than regulatory divergence in developing economies. At the same time, we emphasize that this result reflects a robust empirical association rather than a formally identified causal relationship.

Second, we document what we term the "digital provisions puzzle." The marginal effect of adding specific digital chapters to trade agreements is small—approximately 5%—and consistently weaker than the effect of general trade liberalization. We interpret this pattern as evidence that connectivity infrastructure is a prerequisite for digital trade provisions to generate meaningful gains. This finding should not be read as evidence that legal harmonization lacks value. General PTAs are associated with a substantial 33% increase in trade, demonstrating that trade agreements facilitate digital commerce. Rather, the evidence suggests that, within the CAREC context, physical infrastructure remains the more binding constraint and that digital provisions are likely to become more effective once a sufficient connectivity baseline has been established.

Finally, the simulation analysis provides an indicative estimate of the opportunity cost associated with the region's connectivity deficit. Our central estimates suggest that closing this gap could generate between \$915 million annually under the regional convergence scenario and \$1,186 million under the ASEAN benchmark scenario. These figures are anchored to the statistically significant infrastructure elasticity estimated in the gravity model and should be interpreted cautiously. The confidence intervals reported in Tables 5 and 6 indicate substantial uncertainty, and the estimates are best viewed as order-of-magnitude projections rather than precise forecasts. Nonetheless, the central finding remains consistent across all specifications: physical connectivity is the dominant

correlate of digital trade participation across the country pairs in our sample. As infrastructure improves in the lagging CAREC economies, digital provisions embedded in existing and future trade agreements are likely to become increasingly effective. An infrastructure-first strategy should therefore be viewed as a complement to, rather than a substitute for, continued efforts toward regional trade integration.

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Appendix

Table A1: Welfare gain sensitivity to elasticity of substitution (σ)

σ	β (lower 95% CI = 2.181) \$M	β (central = 3.769) \$M	β (upper 95% CI = 5.357) \$M
Scenario 1 — CAREC Median			
$\sigma = 5$	124	229	349
$\sigma = 7$	82	153	233
$\sigma = 9$	62	115	175
$\sigma = 11$	49	92	140
Scenario 2 — ASEAN Benchmark			
$\sigma = 5$	158	297	460
$\sigma = 7$	105	198	307
$\sigma = 9$	79	148	230
$\sigma = 11$	63	119	184

Note: This table reports welfare-equivalent real income gains rather than export-volume gains. Export-volume effects, which are invariant to σ under the CES framework used in this study, are reported separately in Tables 5 and 6. Welfare gains were measured in USD millions and were calculated as (trade-volume change fraction)/($\sigma - 1$) \times baseline exports, following Arkolakis, Costinot, and Rodríguez-Clare (2012). Rows report the aggregate welfare-equivalent income gains for the five below-median CAREC economies. Columns report estimates based on the central infrastructure elasticity and its 95% confidence interval, derived from the estimated standard error of β (SE = 0.810) in Column (2) of Table 2.

Table A2: Infrastructure elasticity heterogeneity by development level

	(1) Full sample	(2) LIC/LMIC pairs	(3) HIC pairs	(4) CAREC pairs
Digital Infrastructure	3.769*** (0.810)	3.047** (1.453)	4.784** (1.866)	6.873*** (2.018)
PTA	0.264*** (0.054)	0.260** (0.101)	0.274*** (0.060)	0.495*** (0.125)
PTA × Digital Provisions	-0.215*** (0.052)	-0.131 (0.103)	-0.226*** (0.059)	-0.170 (0.118)
Exporter-year FE	Yes	Yes	Yes	Yes
Importer-year FE	Yes	Yes	Yes	Yes
N	622,378	340,367	282,011	63,457
Pseudo R ²	0.931	0.930	0.924	0.877

Note: All models were estimated using PPML (ppmlhdfc) with exporter-year and importer-year fixed effects. Standard errors clustered at the country-pair level are reported in parentheses. The dependent variable is Broad Digital Trade, measured in USD millions. Income-group classifications follow World Bank FY2021 definitions. Column (2) includes all country pairs in which at least one country is classified as LIC or LMIC. Column (3) includes pairs in which both countries are classified as HIC. Column (4) includes all country pairs involving at least one CAREC member. The interaction between digital infrastructure and the LIC/LMIC indicator is statistically insignificant ($\beta = 1.293$, SE = 1.332, $p = 0.332$), indicating no statistically significant difference in the infrastructure elasticity across income groups and supporting the use of a pooled specification. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A3: Welfare gain sensitivity using CAREC-specific infrastructure elasticity

σ	S1 Welfare Gain \$M (CAREC $\beta=6.873$)	S2 Welfare Gain \$M (CAREC $\beta=6.873$)	Ratio vs Table A1 central ($\beta=3.769$)
$\sigma = 5$	480	644	2.1
$\sigma = 7$	320	429	2.1
$\sigma = 9$	240	322	2.1
$\sigma = 11$	192	258	2.1

Note: Welfare gains are reported in USD millions, calculated as (trade-volume change fraction)/($\sigma - 1$) \times baseline exports, following Arkolakis, Costinot, and Rodríguez-Clare (2012). The calculations used the infrastructure elasticity estimated for CAREC-involved country pairs ($\beta = 6.873$, SE = 2.018, $p = 0.001$; N = 63,457), reported in Column (4) of Appendix Table A2. These estimates should be interpreted as an indicative upper-bound scenario. The CAREC-specific elasticity was derived from a substantially smaller sample than the full-sample elasticity used in Tables 5 and 6, and its 95% confidence interval is correspondingly wide (2.918–10.828). For comparison, the baseline welfare estimates based on the full-sample elasticity ($\beta = 3.769$) are reported in Table A1 ($\sigma = 7$ row: Scenario 1 = \$153M; Scenario 2 = \$198M). The approximately 2.1-fold increase in welfare gains across all values of σ reflects the linear dependence of the welfare formula on β/σ , making the scaling invariant to the assumed elasticity of substitution.